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# The Role of Ocean Climate Data in Operational Naval Oceanography

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## **Abstract**

Local application of global-scale models describes the U.S. Navy's basic philosophy for operational oceanography in support of fleet operations. Real-time data, climatologies, coupled air/ocean models, and large scale computers are the essential components of the Navy's system for providing the warfighters with the performance predictions and tactical decision aids they need to operate safely and efficiently. In peacetime, these oceanographic predictions are important for safety of navigation and flight. The paucity and uneven distribution of real-time data mean we have to fall back on climatology to provide the basic data to operate our models. The Navy is both a producer and user of climatologies; it provides observations to the national archives and in turn employs data from these archives to establish data bases. Suggestions for future improvements to ocean climate data are offered.

## **Slide 1 - Introduction**

**Think Globally . . . Act Locally.** This slogan, seen on automobile bumper stickers and popular among environmentalists, aptly describes the U.S. Navy's philosophy when it comes to oceanographic support for fleet operations. The Navy's mission is worldwide, but at any given moment, the local environment dominates the operations of every naval component at sea. This fact of life shapes our approach to fleet support. The realization that no organization possesses the capability, or the resources, to satisfy all of the data and information needs on demand, leads to the heavy reliance on ocean climatologies to drive the models that provide the nowcasts and forecasts that are so important to naval operations.

## **Slide 2 - The Process**

There exists a "Process" in operational Naval Oceanography whereby we get from Point A to Point B. That "Process" starts with Data Sources — Space-based, Earth-based, and Data Bases, both real time and historical. These Data Sources feed the Coupled Air/Ocean Models that provide the Operational Systems Performance and Prediction Data, and Tactical Decision Aids. These products go into making Warfighting Decisions. A subset of these products, I might add, are an important aspect of peacetime operations, as they are essential components of safety of navigation and flight.

### **Slide 3 - Ocean-Atmosphere Models**

Nowcasts and forecasts are the results of high resolution, coupled ocean-atmosphere models that are used to predict future ocean states on a basin-wide scale.

### **Slide 4 - Model Output**

This slide shows the output of a recently-developed one-eighth degree latitude, multi-layered ocean circulation model of the North Pacific Ocean. This model relies on climatology, real-time data, and high speed, large scale computers to function. The outputs of such regional models are the basic parameters that go into military applications models that predict sensor and weapons performance at some specific time and location in that ocean basin.

### **Slide 5 - High Resolution Features**

This slide is a blow up of the previous one showing the fine detail that is resolved by the model.

### **Slide 6 - Real Time Data and Climatology**

High resolution ocean models are driven by data — both real time and climatological.

### **Slide 7 - Sources of Real Time Data**

Sources of real time observations are satellites, ships, aircraft, and drifting buoys — both of military and civilian origin .

### **Slide 8 - Source Statistics**

This slide shows a breakdown of the sources of the more than a quarter million observations received daily, on average, at the Fleet Numerical Oceanography Center in Monterey, California. Of these, half are for the ocean, the rest are for the land and the atmosphere. That number for the oceans is misleading, however, since it includes the approximately 120,000 Multi-Channel Sea Surface Temperature reports from meteorological satellites. With these removed, a woeful 1% of all observations received at FNOC are oceanographic.

**Slide 9 - Source Breakdown**

This slide provides a further breakdown of the worldwide source of the data received at FNOC on a typical day. Only the first three types of data are in situ oceanographic observations.

**Slide 10 - Climatology**

Given the paucity and uneven dispersion of the real-time data, we must fall back on climatology to provide the basic data to operate our models.

**Slide 11 - Navy Data Bases**

The U.S. Navy compiles and maintains an array of climatologies to support a wide variety of prediction models. Two of these involve ocean climate data. MOODS — the Master Oceanographic Observation Data Set — is a data base containing over 4.5 million profiles of quality-controlled observations of temperature, temperature and salinity, and sound velocity. GDEM — the Generalized Digital Environmental Model — takes the MOODS data base and, using a four-dimensional steady state digital model of ocean temperature and salinity, interpolates in time and space, and provides profiles of historical temperature and salinity over all ocean areas with bottom depth greater than 100 meters.

**Slide 12 - Surface Winds Climatology**

This slide is a typical output of one of the climatologies developed by the Naval Oceanography Command's Detachment at the National Climate Data Center in Asheville, North Carolina.

**Slide 13 - Large Scale Computers**

The assimilation of large and diverse data sets requires very powerful computing capabilities. For this the Navy has acquired two Class VII supercomputers — a CRAY Y-MP-8 at the Naval Oceanographic Office in Mississippi, and a CRAY Y-MPC90 at Fleet Numerical Oceanography Center in Monterey.

**Slide 14 - Primary Oceanographic Prediction System**

The first Large Scale Computer is installed and is up and running at the Naval Oceanographic Office, Stennis Space Center, Mississippi. The second is on order and is expected to become operational at the Fleet Numerical Oceanography Center in Monterey, California later this year or the beginning of next. In addition

to ingesting and manipulating large amounts of data, the supercomputers, their peripheral hardware and software — which collectively we call the Primary Oceanographic Prediction System — will run the operational forecasts for day to day fleet support. As the slide indicates, there is sufficient reserve for research and development, and for the evaluation of developmental models. We have configured the system so that we can accommodate federal and academic researchers who have need for access to a supercomputer, at very economical rates. This should be of particular value to the climate change research community.

### **Slide 15 - Naval Applications of Climatology**

This slide conceptualizes the role of climate data in operational Naval Oceanography as it is currently applied. Essentially, the real-time observations, which are mostly from satellites, and therefore two-dimensional, are combined with model output data from previous runs to update climatologies, allowing extension of the data fields to the third dimension, the vertical. This newly derived data set is used to initialize the operational models that provide the fourth dimension, time, allowing the production of oceanographic predictions. These are the up-to-date operational products that naval components around the world can access to activate the sensor and weapon performance predictions and tactical decision aids that were, if you recall, in the top box of the earlier slide describing the "Process." These are the deliverables in military parlance.

### **Slide 16 - Navy a Consumer and Producer of Ocean Data**

It is important to remember that when it comes to both real time data and climatologies, the U.S. Navy is both a consumer and a producer. We employ the climatological data that is available in the national archives, such as the National Oceanographic Data Center. We also make real-time use of the earth observing sensors aboard the NOAA polar orbiting meteorological satellites. In turn, data collected from our Navy ships, such as Expendable Bathythermograph data, are made available to NODC for archiving. And, sensor data from the Department of Defense's Defense Meteorological Satellite Program are also made available to the appropriate national archive facilities for further use and dissemination. These are only a few of many examples of such cooperation and mutual benefit.

The Oceanographer of the Navy is actively supporting the production of marine atmospheric climatologies through the day-to-day efforts of the Commander, Naval Oceanography Command's Detachment at the National Climatic Data Center, Asheville, North Carolina.

Finally near-real-time access to Navy oceanographic and meteorological products is available to the civilian community through the NOAA facilities colocated with the Fleet Numerical Oceanography Center in Monterey.

## **Slide 17 - Improvements**

Since the stated Workshop objectives are to identify ways to improve: "data management," "access to marine data," "management systems to support ocean monitoring and predictions," and "data services," I would like to share some thoughts with you on the subject of improvements.

Under the topic of observations:

- We should selectively increase the coverage of ocean observations through a judicious choice of space-based and in situ observations; by carefully employing the most cost-effective technology, and by taking advantage of what we have already learned about the oceans to determine where, how often and at what spatial resolution we need to make these observations to adequately describe the environment so as to make predictions at an acceptable level of accuracy. It would seem that what we are discussing here is relevant to the emerging national and international efforts to coordinate the development of a Global Ocean Observing System. We recognize that many of the U.S. Navy's ocean observing systems could factor into the architecture and implementation of a Global Ocean Observing System.
- We should reduce the uncertainty of measurements by enlisting the best scientific talents of the research community to ensure the quality and appropriateness of measurement techniques; and we should encourage industry to produce reliable, low-cost instrumentation that will meet the twin technical objectives of increased accuracy and coverage.
- We need to extend observations to the shallow water areas of the world to include the coastal regions and semi-enclosed seas. This may require new measurement techniques and instrumentation than that which has been designed for the open ocean, as well as new organizational and cooperative arrangements.

With regard to models:

- We need to improve our predictive models to increase their resolution and extend their predictive range.
- Models need to be developed that couple the ocean with the atmosphere, and with ice cover and the atmosphere in polar regions.
- Models need to be able to assimilate and merge diverse data sets that measure the same parameters. For instance, we need to be able to combine satellite altimetry and sea surface temperature measurements to locate ocean fronts and eddies and to estimate current velocities.
- Finally, we need to extend our high resolution air/ocean models to as-yet-unmodeled regions of the world's oceans and to create reliable models that are applicable to coastal areas and semi-enclosed seas.

As for climatology:

- We need to fill in the spatial and temporal gaps in the record with new observations where necessary, and with as-yet-unarchived data wherever they may be found.

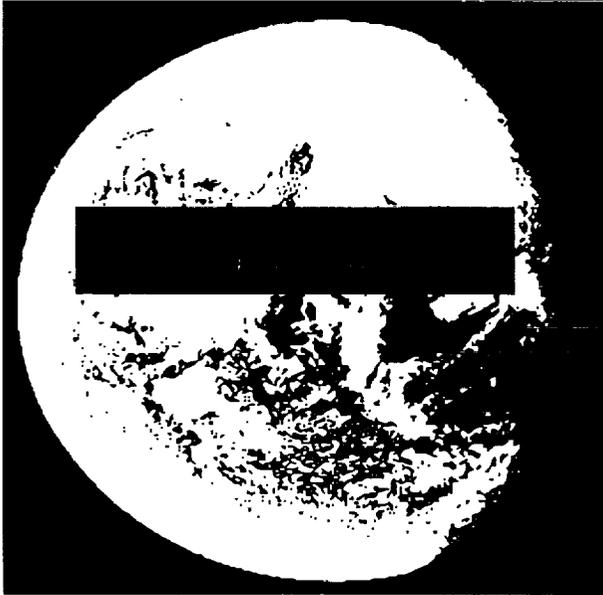
- We need to be able to quantify variability of data at grid points in the climatologies, so as to be able to put meaningful bounds on the limits of predictability in the forecasts.
- Also, we need new climatologies that are the product of different measurement techniques that measure the same parameter — we call this Data Fusion — where such new products improve the accuracy or resolution of the measured parameter.

### **Slide 18 - Conclusion**

In conclusion, ocean climate data are important to our way of doing business in operational Naval Oceanography. The U.S. Navy is interested in the future of climatologies by participating in their improvement through continued contribution of observations and constant research on methods for making most effective use of climatologies in our prediction models.

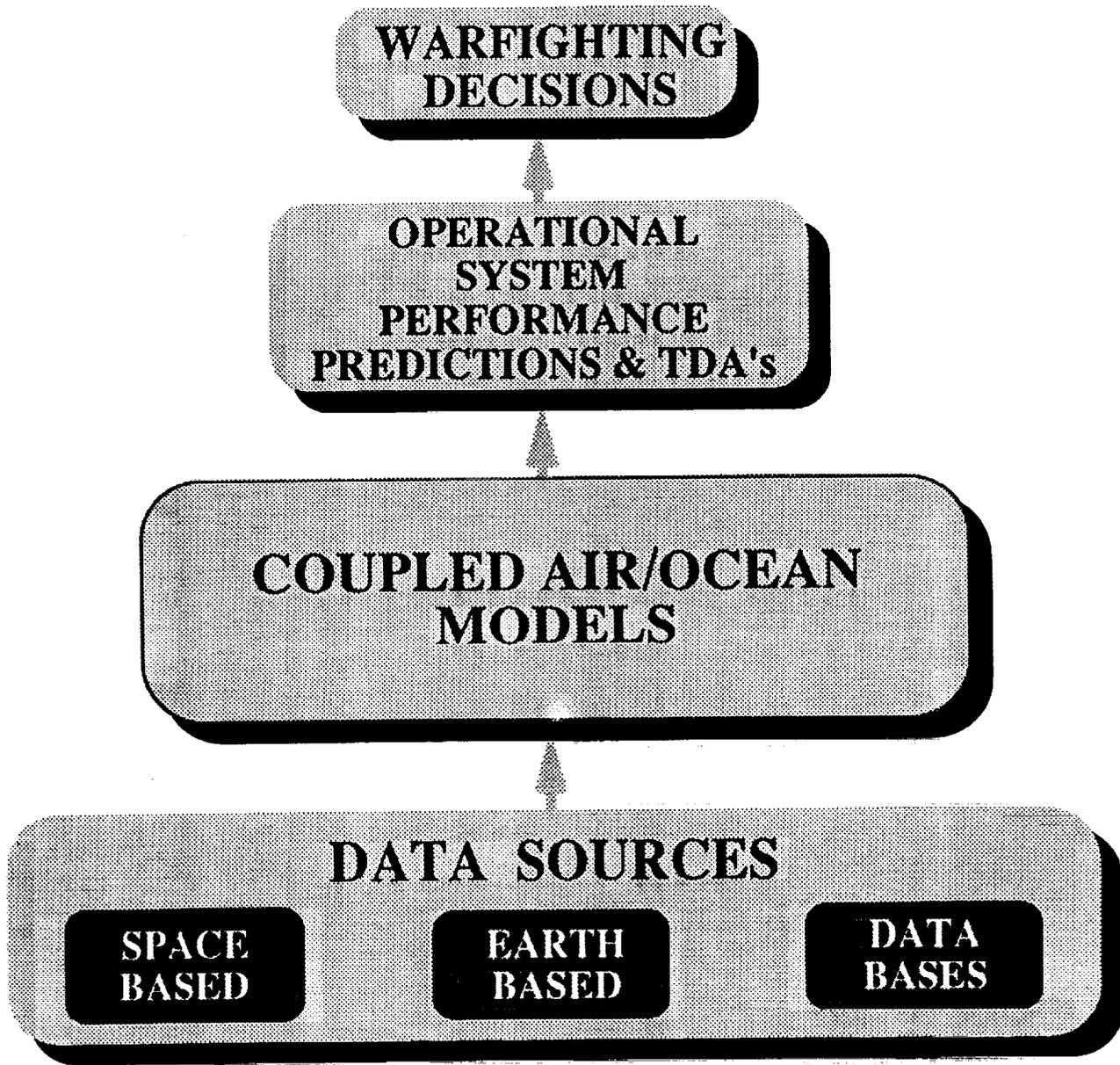
We encourage the participants to pursue the stated objectives of the Workshop to the benefits of all users of ocean climate data, and share with you a mutual interest in the development of ocean climatologies for all of the multitude of purposes they serve.

# Fleet Support



*Slide 1*

# The Process . . .

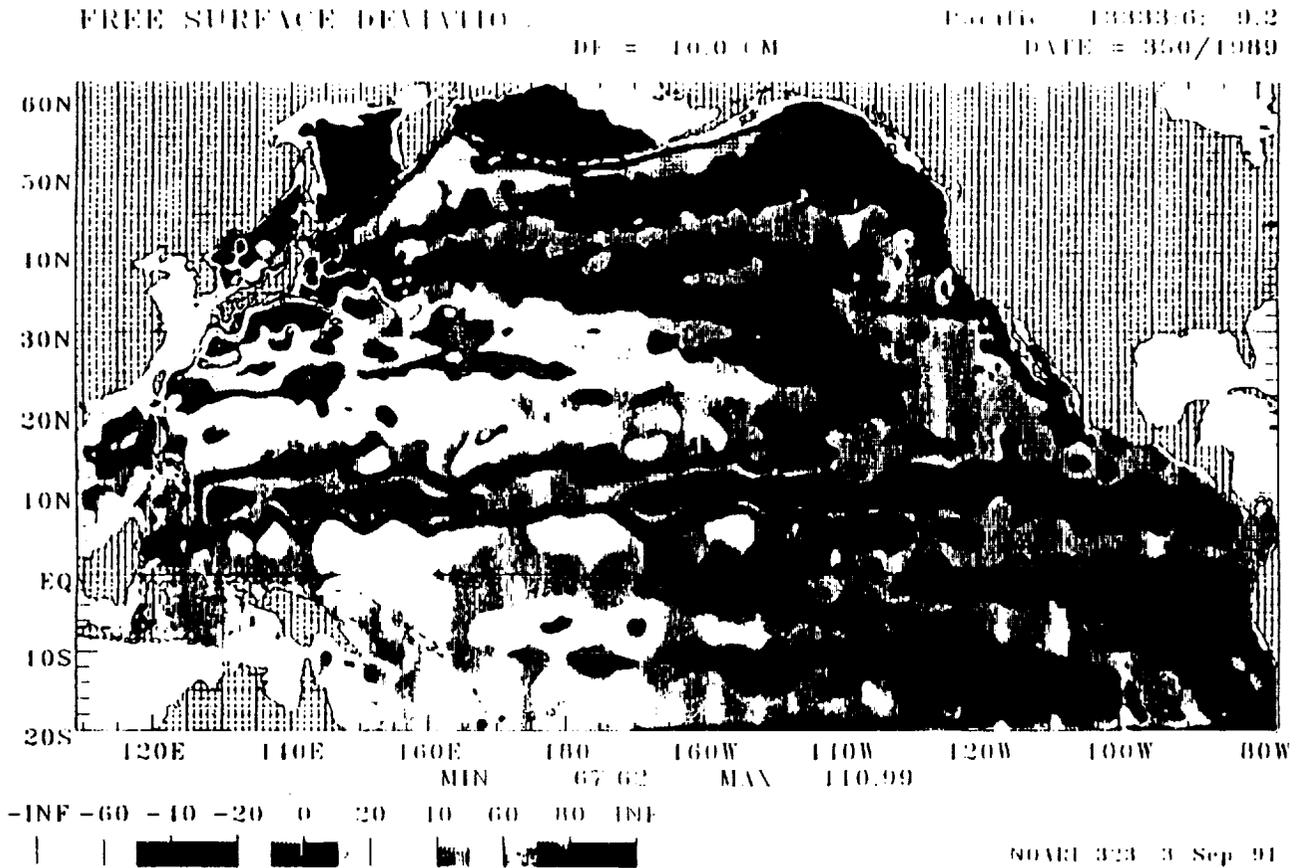


Slide 2

# Nowcasts / Forecasts . . .

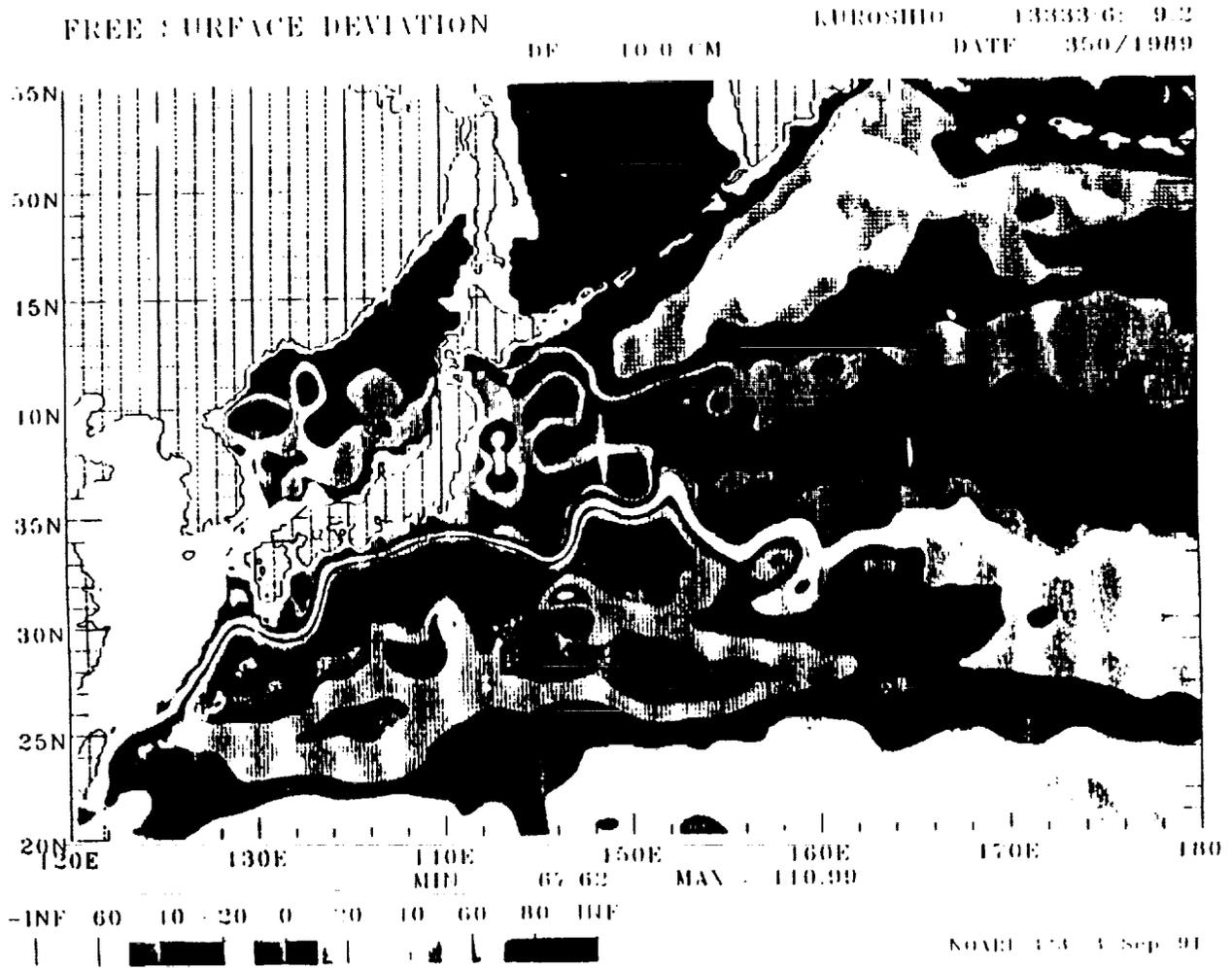
## From High Resolution Global Models

Slide 3



Slide 4

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Slide 5

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## High Resolution, Coupled Ocean-Atmosphere Models . . .

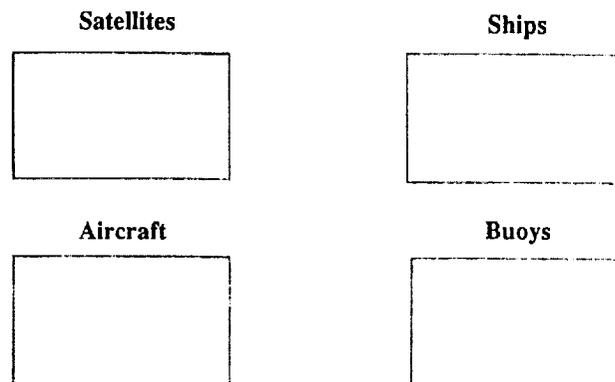
Driven By:

- Real-Time Data Bases

- Climatological Data Bases

*Slide 6*

### Sources Of Observations



*Slide 7*

### Where The Observations Come From

- 236,100 Obs Received Each Day by FNOCC
  - 20% Land
  - 28% Atmosphere
  - 52% Ocean (Note: Only 1% if Satellite SST Removed)
- Source of Obs
  - 65% Satellite
  - 33% Other (Land, Balloon, Rawindsond, Ect.)
  - 1.5% ship
  - 0.5% Buoy

*Slide 8*

# Environmental Data Received And Processed At FNOC Every 24 Hours

<u>Type of Data</u>	<u>Number of Obs</u>
Surface Ship Reports	3,000
Drifting Buoy Reports	200
Bathythermograph Reports	250
Ocean Front and Eddy Positions Inferred from Satellite Imagery	1,000
Pilot Balloon (PIBAL) Reports	1,450
Aircraft Reports (AIREPS)	4,000
Radiosonde (RAOB) Reports	1,600
Satellite Atmospheric Temperature and Moisture Profiles (TOVS)	22,300
Airport Weather Reports (METAR)	24,000
Surface Land Reports	36,000
Hourly Surface Land Reports	12,000
Cloud Track Winds (TSX< TWX)	10,200
Australian Meteorological Bogus	+ 100
<b>Total</b>	<b>116,100</b>
Multi-Channel Sea Surface Temperature (MCSST) reports	+ 120,000
<b>Total</b>	<b>236,100</b>

Slide 9

## High Resolution, Coupled Ocean-Atmosphere Models . . .

Driven By:

- Real-Time Data Bases

- Climatological Data Bases

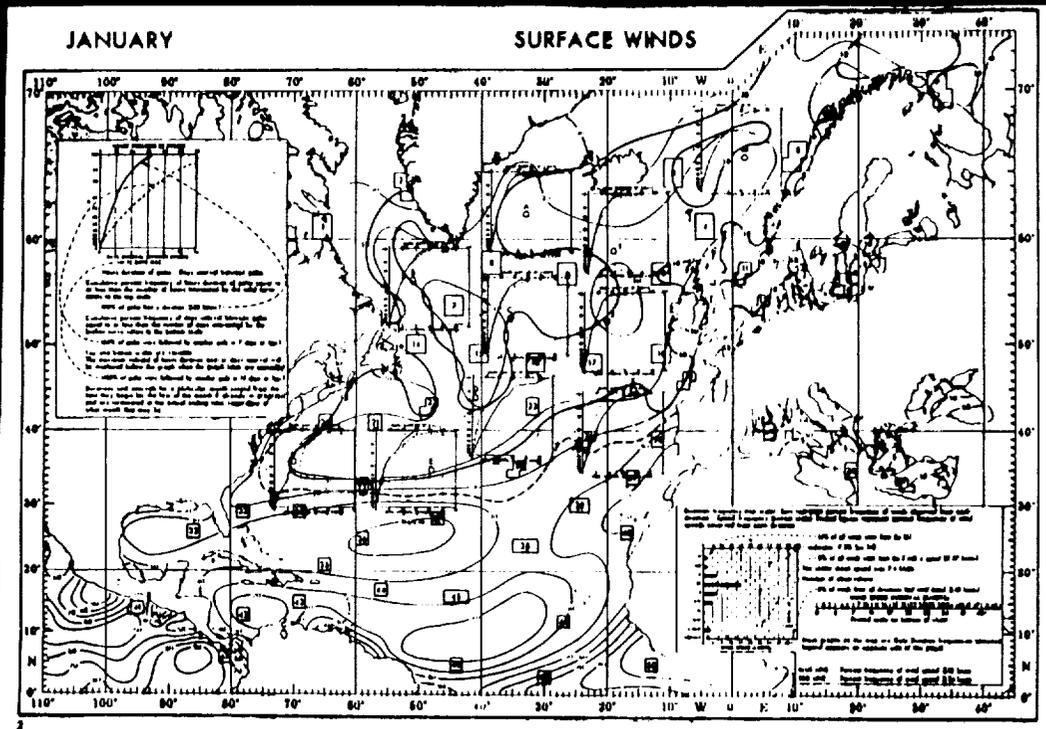
Slide 10

## Navy Climatological Data Bases

- MOODS (Master Oceanography Observation Data Set)
  - 4.5 Million Quality-Controlled Profiles of Temperature, Salinity, and Sound Velocity
- GDEM (Generalized Digital Environmental Model)
  - 4-D Digital Model of Ocean Temperature and Salinity Spatially and Temporally Interpolated

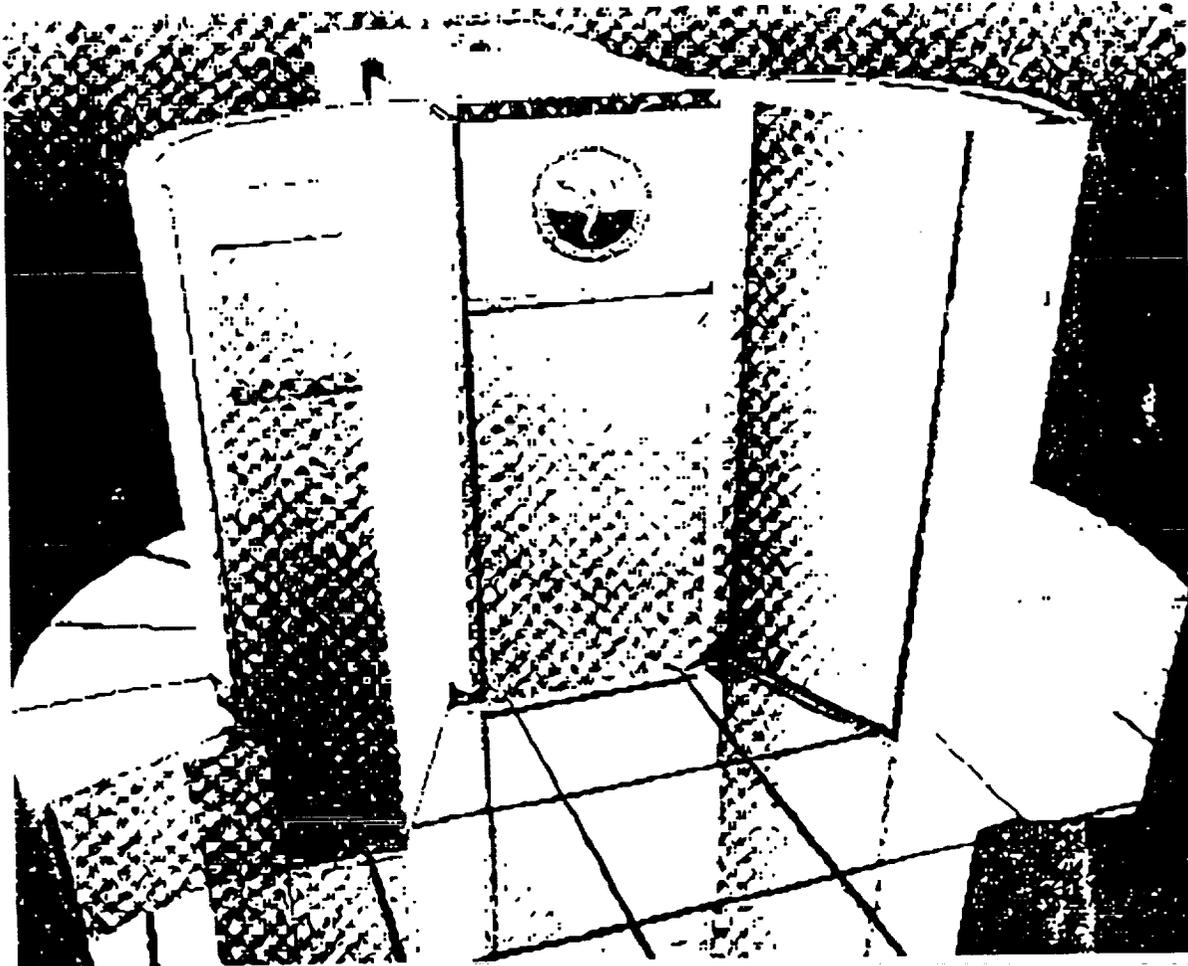
*Slide 11*

## Navy Climatology Sample



*Slide 12*

# Assimilation



*Slide 13*

# **Primary Oceanographic Prediction System**

**POPS-1**  
**Cray Y-MP8/8128**

- **Naval Oceanographic Office (NAVOCEANO)**  
**Stennis Space Center, Ms**
- **Oceanography Related R&D Support**  
**Other CNR Vector Supercomputer Support**  
**CNOC Related Operational Production Support**
- **Planned Emphasis - 50% R&D 50% OPS**  
**Initially Greater Emphasis On R&D**  
**Service Bureau Support Oriented**

**POPS-2**  
**Cray Y-MP8/8128**

- **Fleet Numerical Oceanography Center (FNOC)**  
**Monterey, CA**
- **Operational Production Support**  
**Planned Emphasis - 100% OPS**

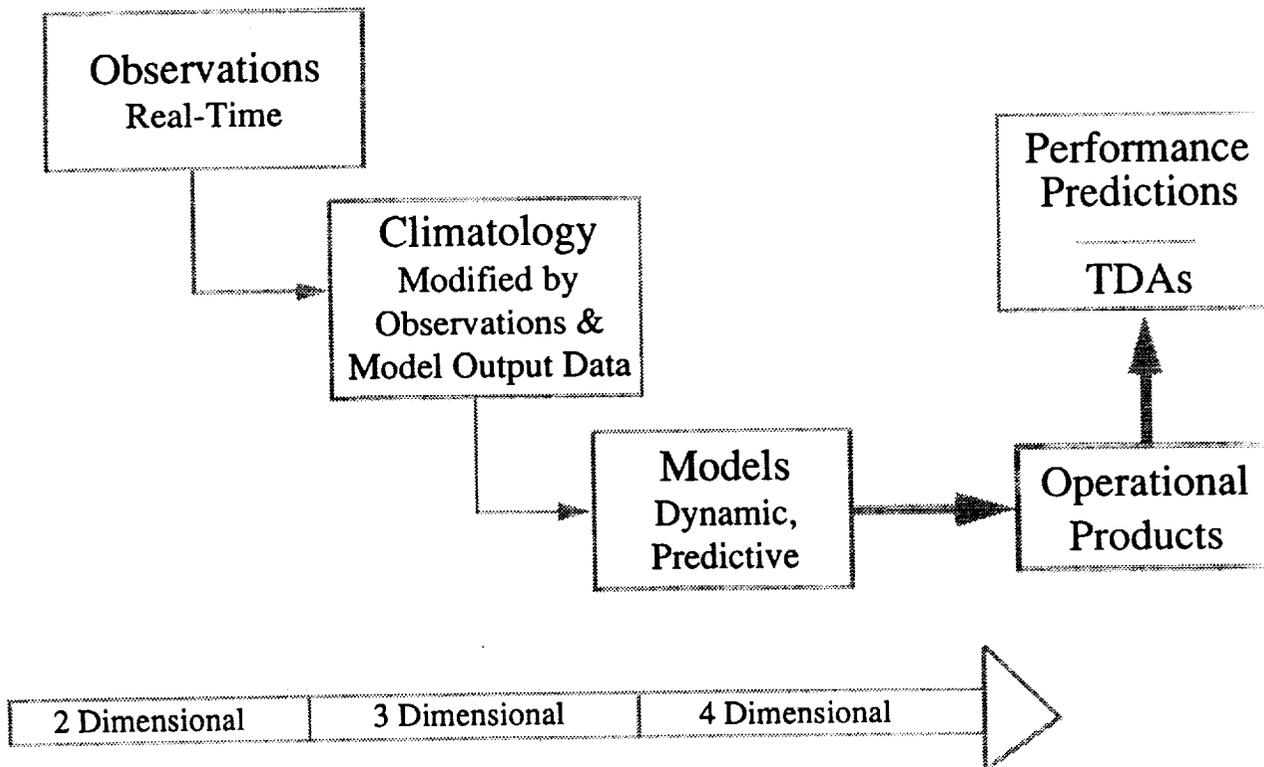


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Slide 14

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# Concept of Operations



Slide 14

## Navy A Consumer And Producer Of Ocean Climate Data

- Consumer
  - Output of National Archives used in Compiling Data Bases
- Producer
  - Navy Ocean Climate Data Provided to National Archives
  - Navy Detachment at NCDC Asheville Produces Marine Climatologies
  - Near-Real-Time Access to FNOC Products Through Co-Located NOAA Facility at Monterey

Slide 16

## Areas For Improvement

- **Observations**
  - Selectively Increase Coverage, Timeliness (GOOS)
  - Reduce Measurement Uncertainty
  - New Frontiers (Coastal and Semi-Enclosed Seas)
- **Models**
  - Increase Resolution; Extend Temporal Range
  - Couple Air/Ocean and Air/Ice/Ocean
  - Assimilate Diverse Data Sets
  - Develop for Unmodelled Regions
- **Climatology**
  - Fill in Gaps (Spatial & Temporal)
  - Quantify Variability
  - New Products (Data Fusion)

*Slide 17*

## Summary

- Ocean Climate Data Essential to Operational Naval Oceanography
- Improvements to Ocean Data Climatologies a Matter of Mutual Interest and Cooperation

*Slide 18*

